Note

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1 Sample

The vector boson samples are generated from MadGraph5 aMC@NLO 3.3.1. Then pass to Pythia for showering and hadronization. Then pass to Delphes for detector simulation.

The processes are the VBF production for doubly charged Higgses $H_5^{\pm\pm}$ and heavy neutral Higgses H_5 with decays $H_5^{\pm\pm} \to W^\pm W^\pm \to jjjj$ and $H_5 \to ZZ \to jjjj$.

Following are the MadGraph scripts for generating W^+ sample:

```
import model GM_NLO
define v = z w+ w-
generate p p > H5pp j j $$v, (H5pp > w+ w+, (w+ > j j), (w+ > j j))
output VBF_H5pp_ww_jjjj
launch VBF_H5pp_ww_jjjj

shower=Pythia8
detector=Delphes
analysis=OFF
done

set param_card tanth 0.226480
set param_card lam2 0.070070
set param_card lam3 -1.331328
set param_card lam4 1.364671
set param_card lam5 -1.963271
set param_card M1coeff 1046.827111
set param_card M2coeff 135.30791
```

```
set run_card nevents 100000
set run_card ebeam1 6500.0
set run_card ebeam2 6500.0
set run_card cut_decays True
set run_card ptj 50
set run_card etaj 3

/home/r10222035/boosted_V_ML_test/Cards/delphes_card.dat

done
```

In Delphes, jets are constructed by the anti-k_t algorithm with $R = 0.7$.

1.1 Sample selection

Only the events that satisfy the following requirement will use for training.

1. The transverse momentum of jets are required $p_{\mathrm{T}} \in (350, 450)$ GeV and in range $|\eta| < 1$.
2. Merging: The angular distance between the two quarks decayed from the vector boson is required $\Delta R(q_1, q_2) < 0.6$.
3. Matching: The vector boson and jet are matched if $\Delta R(V, j) < 0.1$. The events with less than two matching jets will be discarded.

1.2 Sample pre-processing

The jet charge of a jet is defined as

$$\mathcal{Q}_\kappa \equiv \frac{1}{(p_{\mathrm{T},J})^\kappa} \sum_{i \in J} q_i \times \left(p_{\mathrm{T}}^i\right)^\kappa \tag{1}$$

where i represents the constituent in the jet J.

1.2.1 Jet image

After the sample selection, we can construct the jet image of the matching vector boson jet. The jet image is constructed by the following steps:

1. Centralization: Calculating the p_{T} weighted center in η, ϕ plane, then shift this point to origin.

2. Rotation

3. Flipping

4. Pixelating in $\Delta\eta = \Delta\phi = 1.6$ box, with 75×75 pixels.

1.3 Plots

Figure 1 is the jet mass distribution.

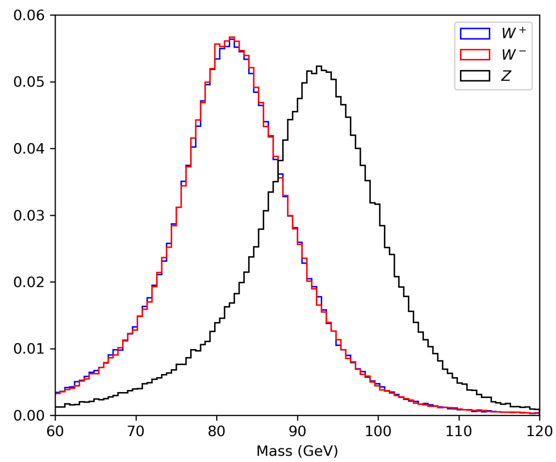


Figure 1: Jet mass distributions of their vector boson samples.

Figure 2 is the jet charge distributions with different κ.

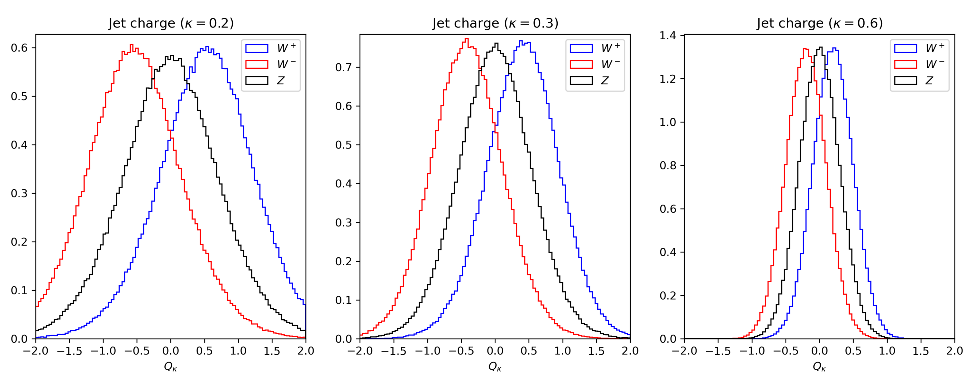


Figure 2: $\mathcal{Q}_\kappa$ distributions of vector boson samples.

Figure 3, 4 are the average jet images of p_{T} and $\mathcal{Q}_\kappa$. Figure 5 is the Z jet image minus W^+ jet image in p_{T} channel.

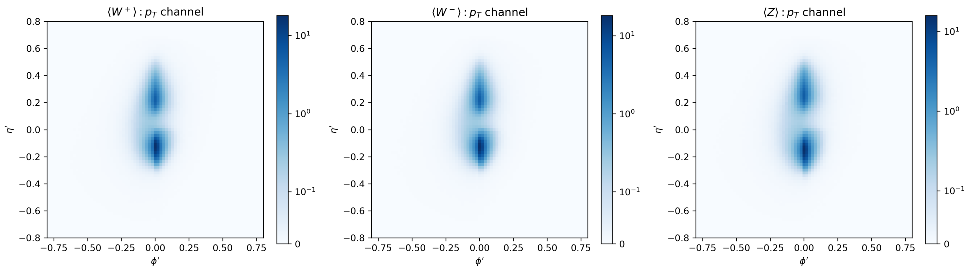


Figure 3: Average of jet images in the p_{T} channel.

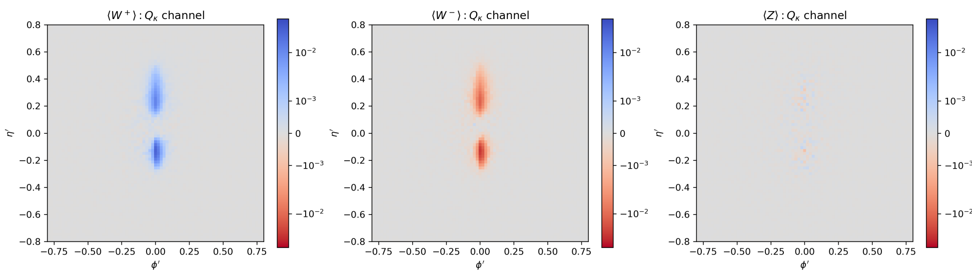


Figure 4: Average of jet images in the $\mathcal{Q}_\kappa$ channel, with $\kappa = 0.15$.

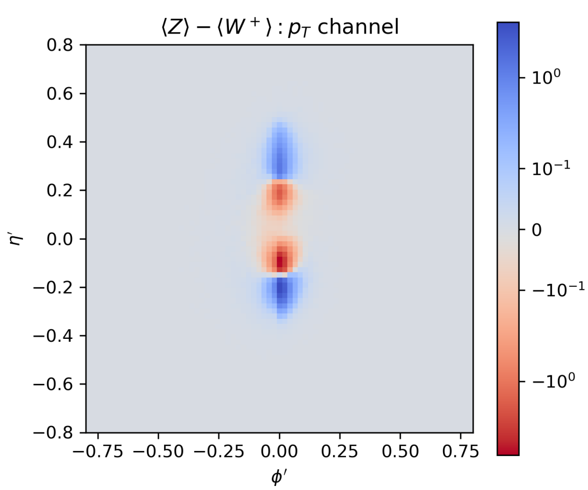


Figure 5: The difference between the Z and W^+ average jet images in p_{T} channel.

2 BDT

The input features are jet mass $\mathcal{M}$ and jet charge $\mathcal{Q}_\kappa$.

2.1 BDT training

Use the GBDT implemented by scikit-learn. The parameters are set as the default setting in sklearn.

The training and testing sample size are in Table 1.

Table 1: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Testing set
1	$14k + 15k + 13k$	$3k + 3k + 3k$
2	$100k + 105k + 90k$	$25k + 26k + 22k$
3	$242k + 257k + 221k$	$60k + 64k + 54k$

2.2 BDT results

The training results are summarized in Table 2. The ROC of BDT for $\kappa = 0.3$ is presented in Figure 6.

Table 2: The training results of BDT for different κ samples.

			W^+		W^-		Z	
	Sample	Overall ACC	AUC	ACC	AUC	ACC	AUC	ACC
BDT $\kappa = 0.15$	1	0.644	0.808	0.773	0.812	0.766	0.812	0.770
BDT $\kappa = 0.30$		0.649	0.822	0.778	0.822	0.769	0.814	0.773
BDT $\kappa = 0.15$	2	0.646	0.808	0.769	0.815	0.765	0.809	0.774
BDT $\kappa = 0.30$		0.652	0.820	0.774	0.826	0.772	0.810	0.775
BDT $\kappa = 0.15$	3	0.648	0.811	0.769	0.817	0.767	0.810	0.775
BDT $\kappa = 0.30$		0.654	0.824	0.776	0.829	0.773	0.811	0.774

3 CNN

The inputs are the jet image of p_T and $\mathcal{Q}_\kappa$.

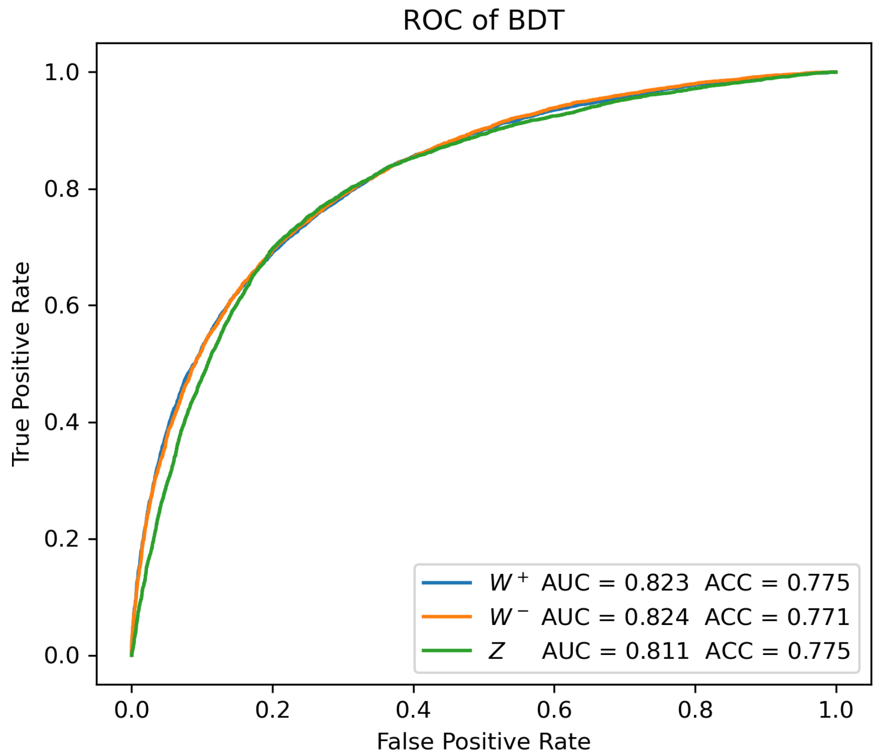


Figure 6: The ROC of BDT. Case W^+ means take W^+ samples as signal and W^-, Z as background.

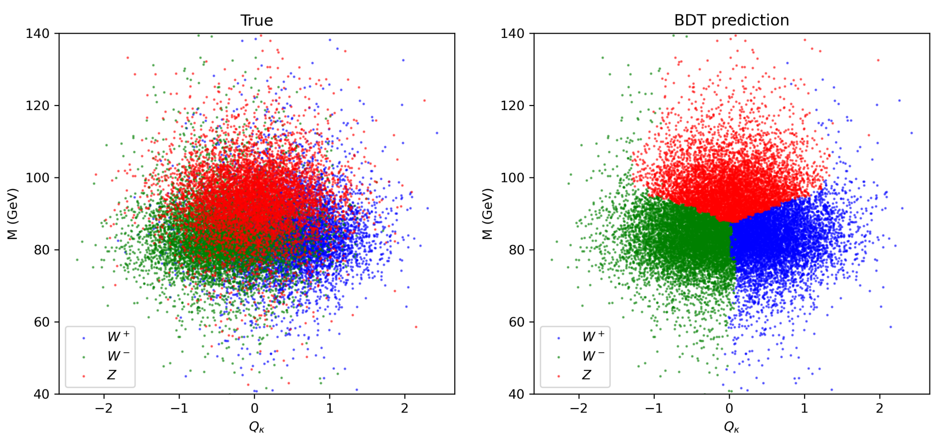


Figure 7: The left plot shows the true distributions for W^+, W^-, Z in the $(\mathcal{Q}_\kappa, \mathcal{M})$ plane (for $\kappa = 0.3$). The right plot is the BDT prediction.

3.1 CNN training

The training, validation, and testing sample size are in Table 3.

Table 3: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Validation set	Testing set
1	$11k + 12k + 10k$	$2k + 2k + 2k$	$3k + 3k + 3k$
2	$80k + 84k + 72k$	$19k + 21k + 18k$	$25k + 26k + 22k$
3	$194k + 205k + 176k$	$48k + 51k + 44k$	$60k + 64k + 55k$

3.2 CNN results

The training results are summarized in Table 4. The ROC of CNN for $\kappa = 0.15$ is presented in Figure 8.

Table 4: The training results of CNN with different κ samples.

			W^+		W^-		Z	
	Sample	Overall ACC	AUC	ACC	AUC	ACC	AUC	ACC
CNN $\kappa = 0.15$	1	0.639	0.825	0.772	0.829	0.774	0.782	0.768
CNN $\kappa = 0.30$		0.632	0.822	0.771	0.825	0.771	0.786	0.771
CNN $\kappa = 0.15$	2	0.667	0.847	0.790	0.847	0.784	0.828	0.795
CNN $\kappa = 0.30$		0.663	0.843	0.786	0.843	0.779	0.825	0.795
CNN $\kappa = 0.15$	3	0.672	0.849	0.793	0.851	0.787	0.834	0.799
CNN $\kappa = 0.30$		0.666	0.845	0.788	0.847	0.783	0.832	0.800

4 CNN^2

4.1 CNN^2 training

The training, validation, and testing sample size are in Table 5.

4.2 CNN^2 results

The training results are summarized in Table 6.

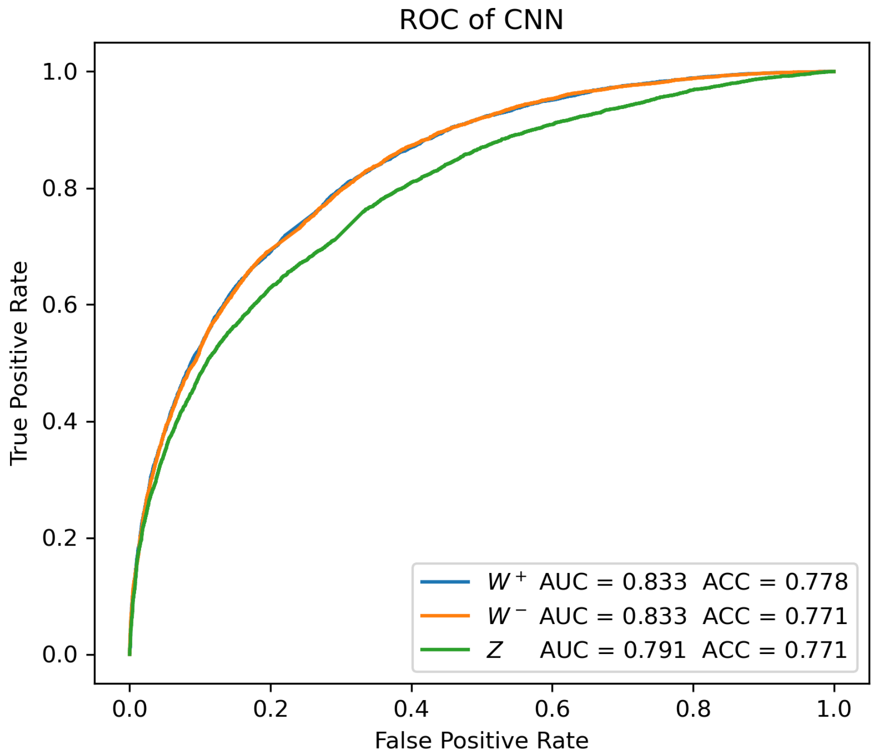


Figure 8: The ROC of CNN for $\kappa = 0.15$. Case W^+ means take W^+ samples as signal and W^-, Z as background.

Table 5: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Validation set	Testing set
1	$11k + 12k + 10k$	$2k + 2k + 2k$	$3k + 3k + 3k$
2	$80k + 84k + 72k$	$19k + 21k + 18k$	$25k + 26k + 22k$
3	$194k + 205k + 176k$	$48k + 51k + 44k$	$60k + 64k + 55k$

Table 6: The training results of CNN^2 for different κ samples.

	Sample	Overall ACC	W^+ AUC	W^+ ACC	W^- AUC	W^- ACC	Z AUC	Z ACC
CNN^2 $\kappa = 0.15$	1	0.642	0.828	0.773	0.831	0.773	0.801	0.780
CNN^2 $\kappa = 0.30$		0.645	0.823	0.773	0.828	0.773	0.802	0.784
CNN^2 $\kappa = 0.15$	2	0.677	0.848	0.792	0.848	0.786	0.842	0.806
CNN^2 $\kappa = 0.30$		0.669	0.842	0.788	0.843	0.780	0.839	0.804
CNN^2 $\kappa = 0.15$	3	0.674	0.848	0.792	0.849	0.785	0.843	0.807
CNN^2 $\kappa = 0.30$		0.675	0.846	0.790	0.847	0.784	0.845	0.808

5 Modify preprocess and preselection

Preprocess: For the vector boson jet which ϕ coordinate across the $\phi = \pm\pi$ boundary, plus its ϕ coordinate by π such that its center is located around $\phi = 0$.

Preselection: Include the events with only one jet that can pass the cuts.

5.1 CNN results for modified preprocess and preselection

The training, validation, and testing sample size are in Table 7.

Table 7: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Validation set	Testing set
1	$313k + 323k + 307k$	$78k + 80k + 76k$	$97k + 100k + 96k$

The training results are summarized in Table 8.

Table 8: The training results of CNN with modified preprocessing and preselection.

	Sample	Overall ACC	W^+ AUC	W^+ ACC	W^- AUC	W^- ACC	Z AUC	Z ACC
CNN $\kappa = 0.15$	1	0.684	0.857	0.798	0.855	0.794	0.828	0.793
CNN^2 $\kappa = 0.15$	1	0.684	0.855	0.797	0.854	0.793	0.835	0.797

5.2 CNN results for Fishbone

The training, validation, and testing sample size are in Table 9. For case 1, only consider the events with 2 jets that can pass the cuts. For case 2, the events with only 1 jet can pass the cuts are included. The training results are summarized in Table 10.

Table 9: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Validation set	Testing set
1	$61k + 65k + 102k$	$15k + 16k + 25k$	$19k + 20k + 32k$
2	$313k + 323k + 307k$	$78k + 81k + 76k$	$97k + 101k + 95k$

Table 10: The training results of CNN with Fishbone's code.

			W^+		W^-		Z	
	Sample	Overall ACC	AUC	ACC	AUC	ACC	AUC	ACC
CNN $\kappa = 0.15$	1	0.694	0.857	0.820	0.856	0.814	0.842	0.776
CNN $\kappa = 0.15$	2	0.682	0.856	0.797	0.854	0.793	0.827	0.791

6 Old sample for training

This section uses the model `GM_UFO` and different parameter settings. The model and parameters are the same as the paper. The selection criteria are the same as Sec.1.1. The events with only one vector boson passing the criteria are included.

Following are the MadGraph scripts for generating W^+ sample:

```
import model GM_UFO
define v = z w+ w-
generate p p > H5pp j j $$v, (H5pp > w+ w+, (w+ > j j), (w+ > j j))
output VBF_H5pp_ww_jjjj-J

launch VBF_H5pp_ww_jjjj-J

shower=Pythia8
detector=Delphes
analysis=OFF
done

set param_card tanth 2.234400e+01
set param_card lam2 1.040100e+00
```

```
set param_card lam3 8.829540e+00
set param_card lam4 -2.232270e+00
set param_card lam5 7.672600e+00
set param_card M1coeff 1.000000e+02
set param_card M2coeff 1.000000e+02

set param_card wt 1.000000e+00
set param_card wz 1.000000e+00
set param_card ww 1.000000e+00
set param_card wh Auto
set param_card wh__2 Auto
set param_card wh3p Auto
set param_card wh3z Auto
set param_card wh5pp Auto
set param_card wh5p Auto
set param_card wh5z Auto

set run_card nevents 10000
set run_card ebeam1 6500.0
set run_card ebeam2 6500.0

/home/r10222035/boosted_V_ML_test/Cards/delphes_card.dat

done
```

6.1 Training results

The training, validation, and testing sample size are in Table 11.

Table 11: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Validation set	Testing set
1	$112k + 116k + 101k$	$27k + 29k + 25k$	$34k + 36k + 31k$
2	$224k + 232k + 201k$	$56k + 58k + 50k$	$69k + 72k + 63k$

The training results are summarized in Table 12. The results are better than the Sec.5.1.

Table 12: The training results of CNN with modified preprocessing and preselection.

	Sample	Overall ACC	W^+ AUC	W^+ ACC	W^- AUC	W^- ACC	Z AUC	Z ACC
CNN $\kappa = 0.15$	1	0.690	0.861	0.798	0.858	0.793	0.830	0.808
CNN^2 $\kappa = 0.15$		0.693	0.860	0.797	0.859	0.794	0.838	0.816
CNN $\kappa = 0.15$	2	0.697	0.864	0.801	0.863	0.796	0.837	0.812
CNN^2 $\kappa = 0.15$		0.698	0.863	0.800	0.862	0.797	0.844	0.818

7 Full event sample

For the full event case, there are six processes: $H_5^{\pm\pm} \to W^\pm W^\pm \to jjjj$, $H_5^{\pm} \to W^\pm Z \to jjjj$, $H_5 \to ZZ \to jjjj$, $H_5 \to W^+W^- \to jjjj$.

7.1 Full event sample selection

Only the events that satisfy the following requirements will be used for training.

1. The transverse momentum of vector boson jets are required $p_{\mathrm{T}} \in (350, 450)$ GeV and in range $|\eta| < 1$.
2. Merging: The angular distance between the two quarks decayed from the vector boson is required $\Delta R(q_1, q_2) < 0.6$.
3. Matching: The vector boson and jet are matched if $\Delta R(V, j) < 0.1$. The events with less than two matching jets will be discarded.

7.2 Full event sample pre-processing

7.2.1 Event image

After the sample selection, we can construct the event image. The event image contains 2 vector boson jets and 2 forward jets. The vector boson jets are selected by the merging requirement. The forward jets are selected by the highest p_{T} jets from the remaining jets. The event image is constructed by the following steps:

1. Centralization: Calculating the p_{T} weighted center in ϕ coordinate, then shift this point to origin.
2. Flipping: Flip the highest intensity quadrant to the first quadrant.
3. Pixelating in $\Delta\eta = \Delta\phi = 6$ box, with 75×75 pixels.

7.3 Event sample plots

Figure 9, 10 are the single event images of p_{T} and $\mathcal{Q}_\kappa$. Figure 11, 12 are the average event images of p_{T} and $\mathcal{Q}_\kappa$.

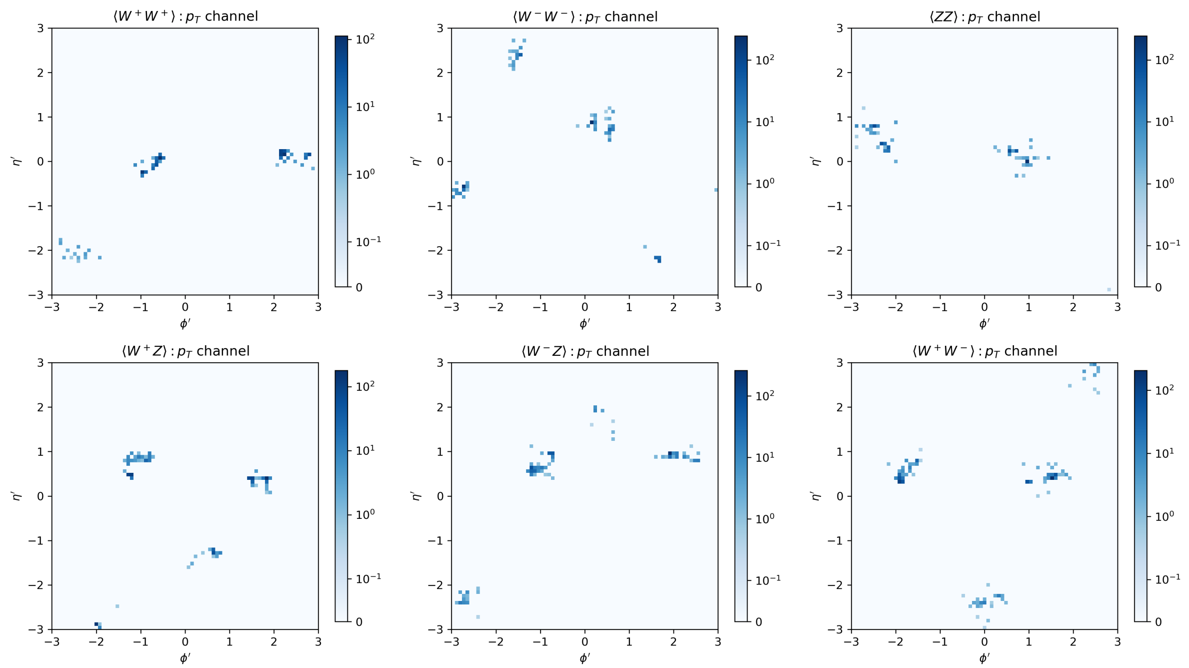


Figure 9: Single event images in the p_{T} channel.

Figure 13 is the ZZ event image minus W^+W^+ event image in p_{T} channel.

8 Correct decay width sample

In this section, the samples are generated with the correct decay widths, i.e., the decay width of t, W, and Z do not change and the exotic Higgses in the GM model are set to “Auto” , meaning the decay widths are calculated by MadGraph.

Following are the MadGraph scripts for generating W^+ sample:

```
import model GM_UFO
define v = z w+ w-
generate p p > H5pp j j $$v, (H5pp > w+ w+, (w+ > j j), (w+ > j j))
output VBF_H5pp_ww_jjjj

launch VBF_H5pp_ww_jjjj
```

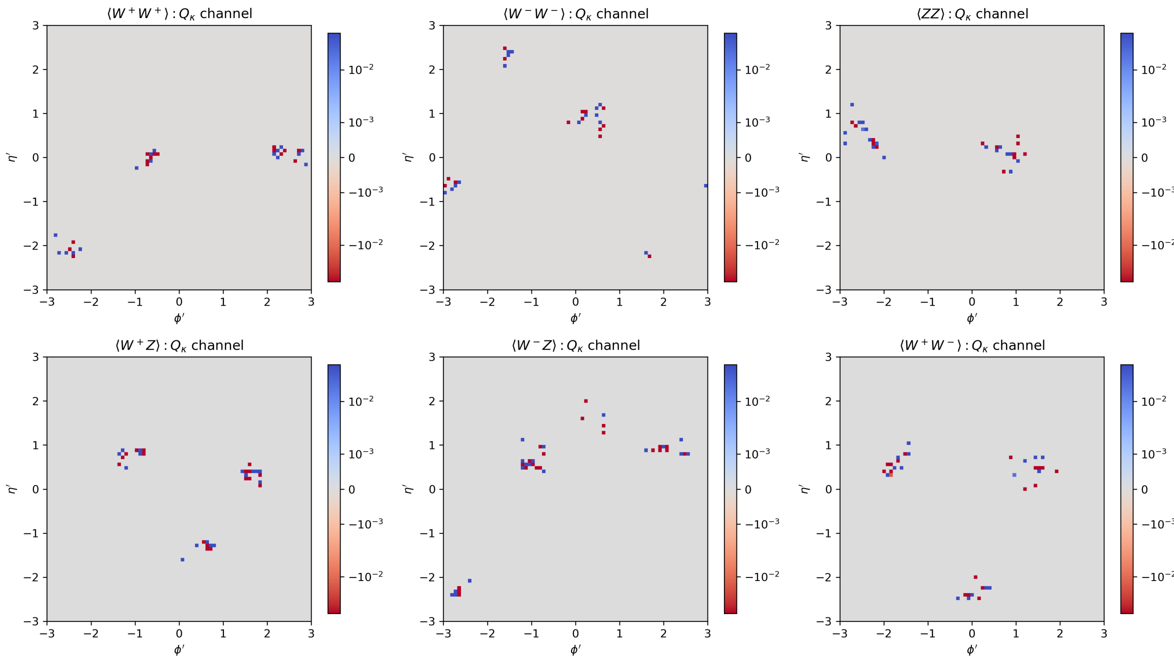


Figure 10: Single event images in the $\mathcal{Q}_\kappa$ channel, with $\kappa = 0.15$.

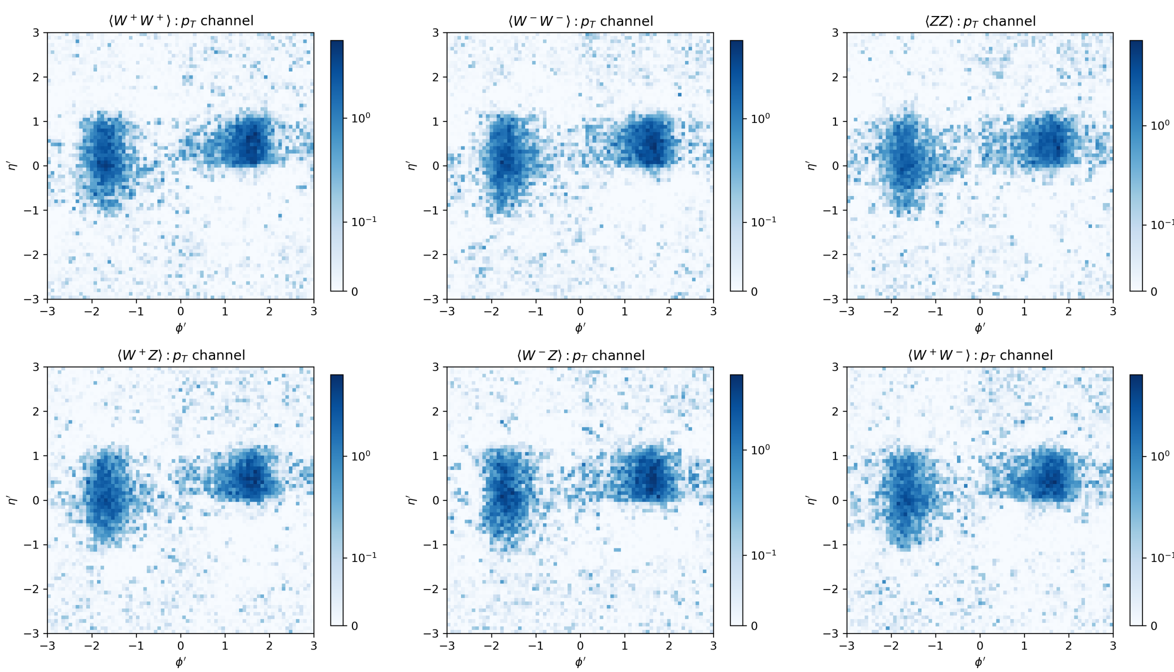


Figure 11: Average of event images in the p_T channel.

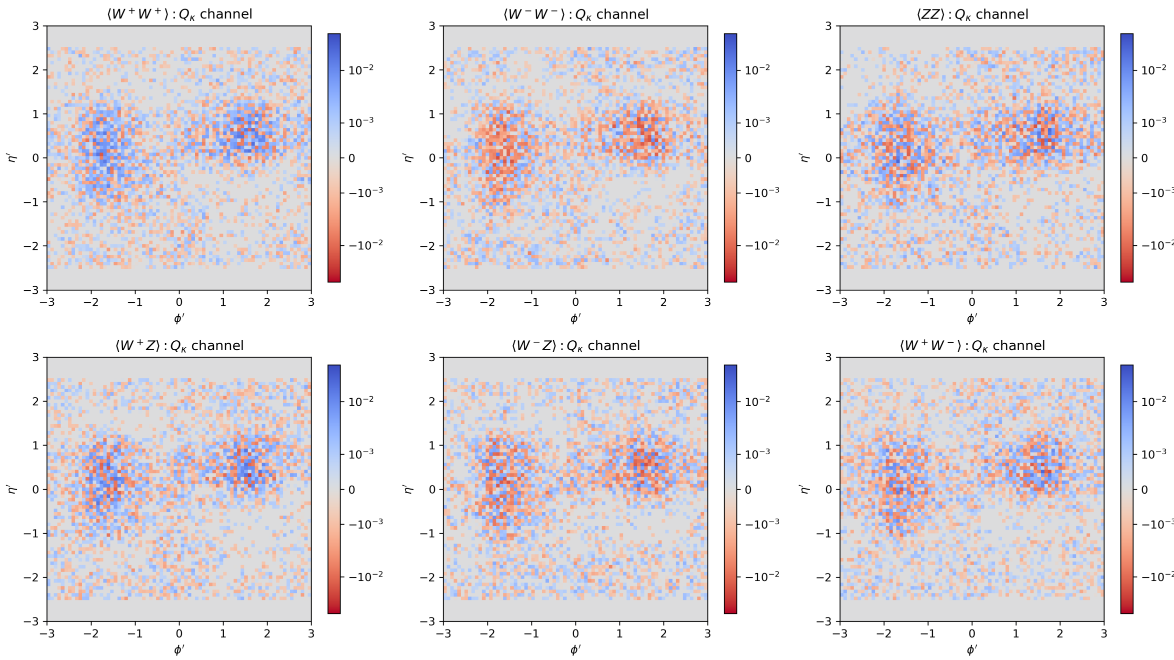


Figure 12: Average of event images in the $\mathcal{Q}_\kappa$ channel, with $\kappa = 0.15$.

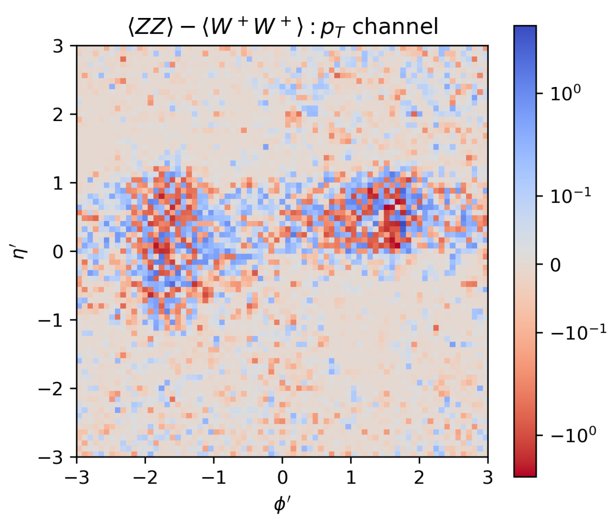


Figure 13: The difference between the ZZ and W^+W^+ average event images in p_{T} channel.

```
shower=Pythia8
detector=Delphes
analysis=OFF
done

set param_card tanth 2.234400e+01
set param_card lam2 1.040100e+00
set param_card lam3 8.829540e+00
set param_card lam4 -2.232270e+00
set param_card lam5 7.672600e+00
set param_card M1coeff 1.000000e+02
set param_card M2coeff 1.000000e+02

set param_card wh Auto
set param_card wh__2 Auto
set param_card wh3p Auto
set param_card wh3z Auto
set param_card wh5pp Auto
set param_card wh5p Auto
set param_card wh5z Auto

set run_card nevents 10000
set run_card ebeam1 6500.0
set run_card ebeam2 6500.0

/home/r10222035/boosted_V_ML_test/Cards/delphes_card.dat

done
```

8.1 Training results

The training, validation, and testing sample size are in Table 13.

Table 13: The entries in the sum correspond to the (W^+, W^-, Z) samples.

Case	Training set	Validation set	Testing set
1	$223k + 232k + 202k$	$56k + 57k + 50k$	$69k + 72k + 62k$

The training results are summarized in Table 14. The results are similar to the Sec.5.1

Table 14: The training results of correct decay width sample. The training results of CNN and CNN^2 are presented with an average and a standard deviation. These values are derived from 10 times training with the same dataset. Yet, the ACC value of each boson is only derived from a single result.

			W^+		W^-		Z	
	Sample	Overall ACC	AUC	ACC	AUC	ACC	AUC	ACC
BDT $\kappa = 0.30$		65.1	82.6	77.5	82.5	77.0	79.2	77.4
CNN $\kappa = 0.15$	1	68.24±0.04	85.72±0.02	(79.5)	85.58±0.02	(79.1)	81.64±0.05	(79.8)
CNN^2 $\kappa = 0.15$		68.26±0.13	85.55±0.04	(79.5)	85.41±0.05	(79.0)	82.22±0.08	(80.2)

but worse than Sec.10.2. It seems that the decay width of t, W, and Z will affect the training results.

Figure 14 is CNN's loss and accuracy curve. Figure 15 is CNN's ROC.

Figure 16 is CNN^2's loss and accuracy curve. Figure 17 is CNN^2's ROC.

9 Full event training

9.1 Training sample size

The event sample size for each type is presented in Table 15

Table 15: The sample size for each type. 80% samples are used in training, and 20% samples are used in testing.

Case	κ	W^+W^+	W^-W^-	ZZ	W^+Z	W^-Z	W^+W^-
1	0.15	47k	51k	38k	42k	44k	48k

9.2 Training results

The training results are summarized in Table 16.

For CNN, the overall accuracy is 45.1%. For CNN^2, the overall accuracy is only 37.9%.

Figure 21 is CNN's ROC. Figure 22 is CNN^2's ROC.

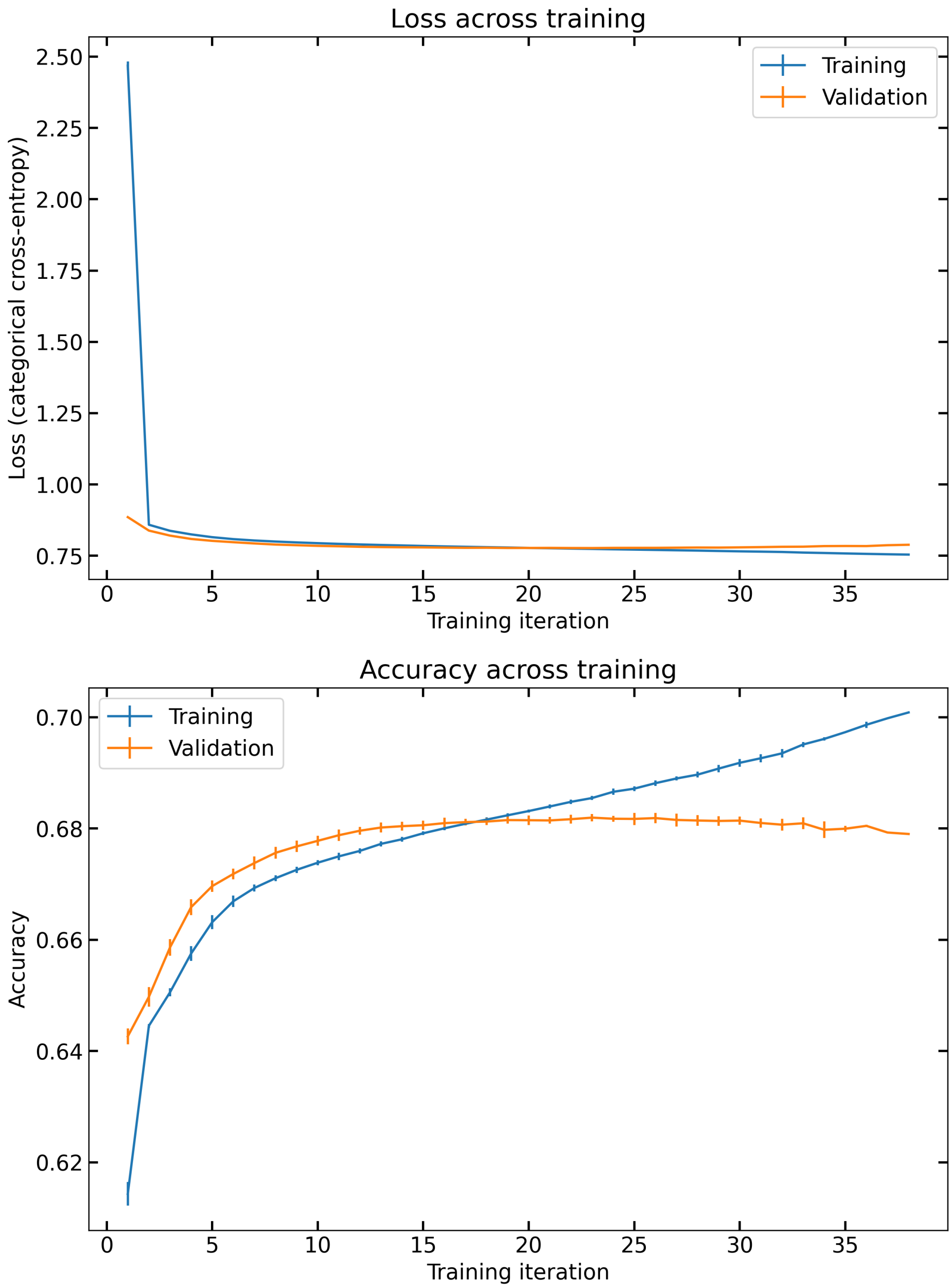


Figure 14: The loss and accuracy curve for the CNN model. Both of them are demonstrated with the average value (solid curve) and the first standard deviation range (error bar).

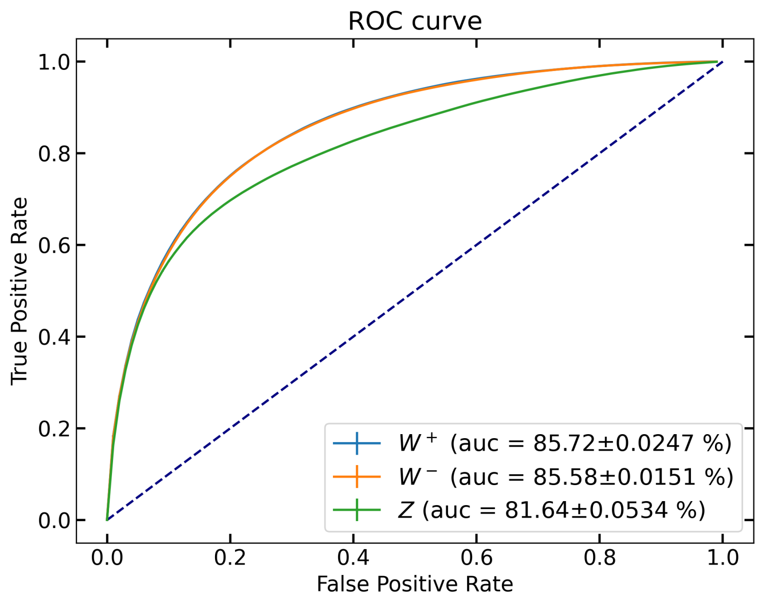


Figure 15: The ROC curve of each vector boson for the CNN model. The plotting scheme is the same as Figure 14.

Table 16: The training results of the full event.

		Overall	W^+W^+		W^-W^-		ZZ		W^+Z		W^-Z		W^+W^-	
	Sample	ACC	AUC	ACC	AUC	ACC	AUC	ACC	AUC	ACC	AUC	ACC	AUC	ACC
CNN	1	0.451	0.860	0.858	0.855	0.850	0.797	0.868	0.740	0.845	0.737	0.842	0.741	0.830
CNN^2		0.379	0.830	0.846	0.822	0.837	0.684	0.858	0.687	0.842	0.686	0.840	0.690	0.826

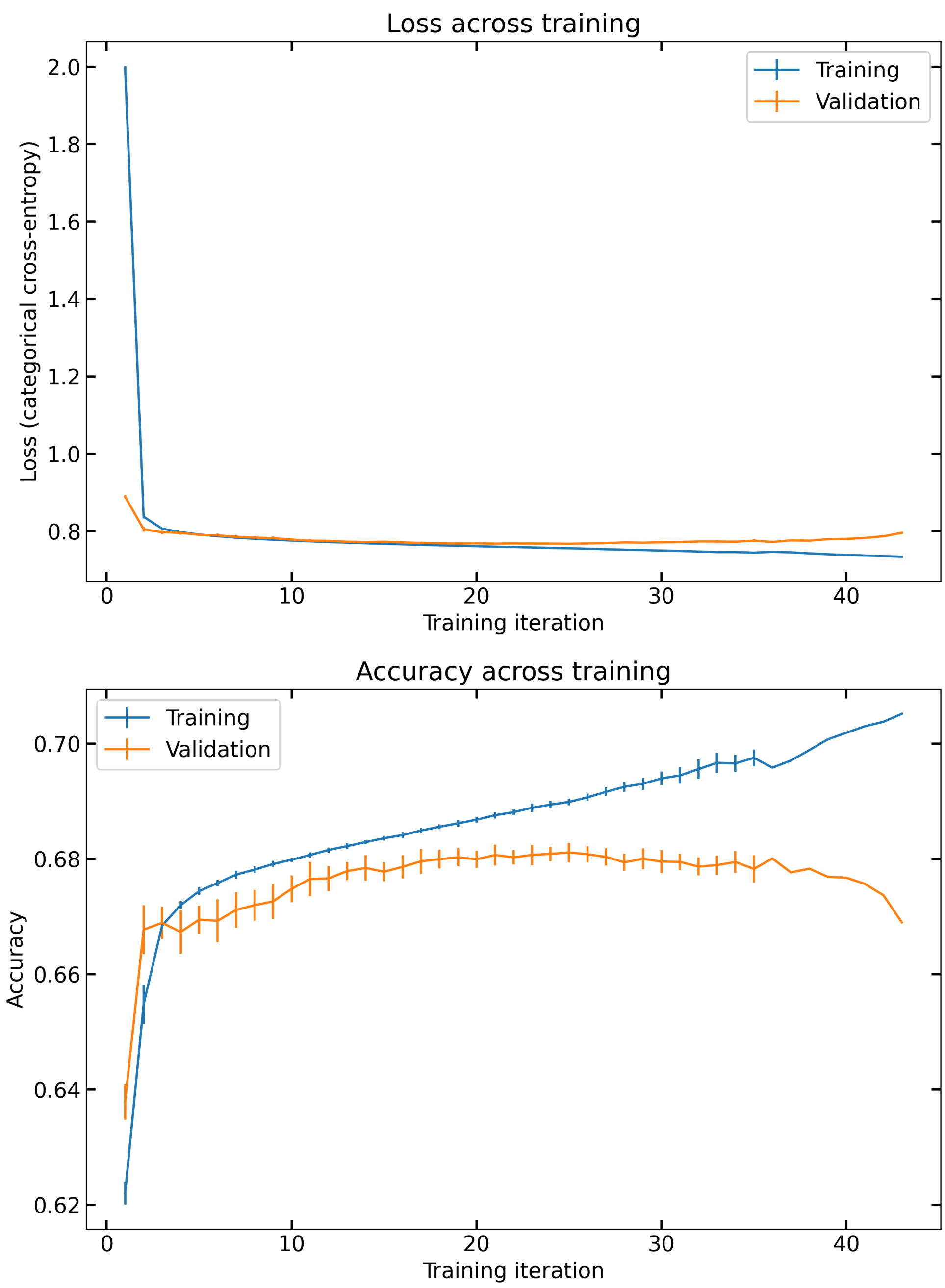


Figure 16: The loss and accuracy curve for the CNN^2 model. The plotting scheme is the same as Figure 14.

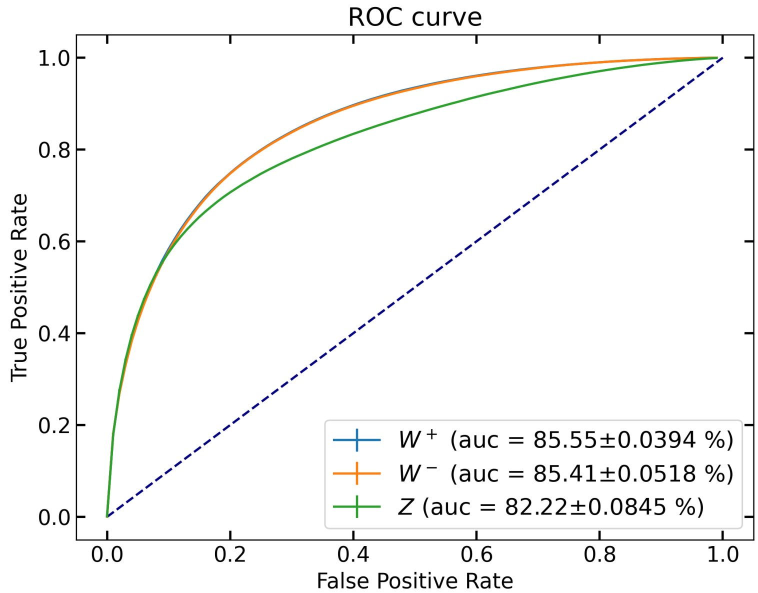
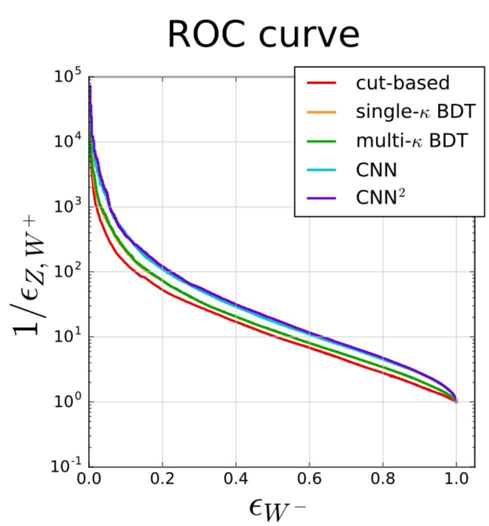
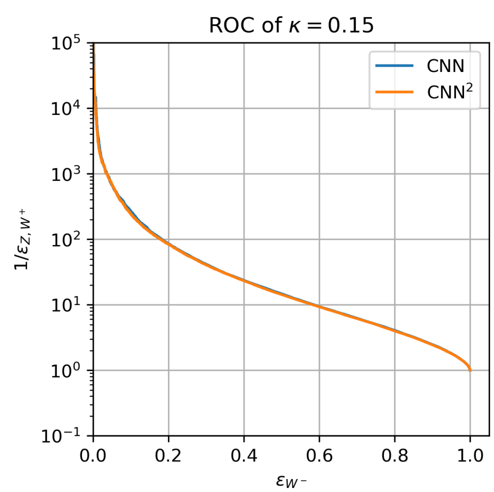


Figure 17: The ROC curve of each vector boson for the CNN^2 model. The plotting scheme is the same as Figure 14.

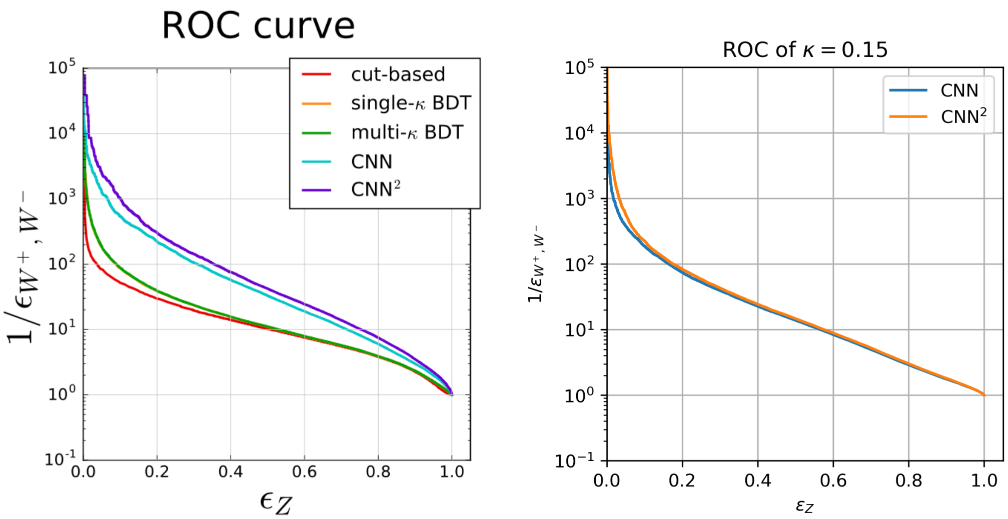


(a) Paper



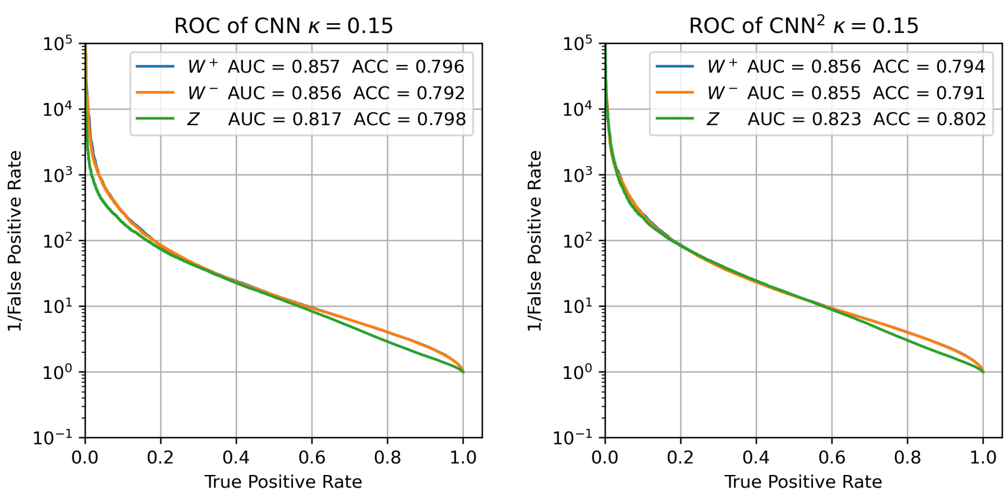
(b) Ours

Figure 18: The signal W^- ROCs. Left is paper. Right is my result.



(a) Paper (b) Ours

Figure 19: The signal Z ROCs. Left is paper. Right is my result.



(a) CNN (b) CNN^2

Figure 20: The ROCs of my training results. For the left one, the model is CNN. For right one, the model is CNN^2.

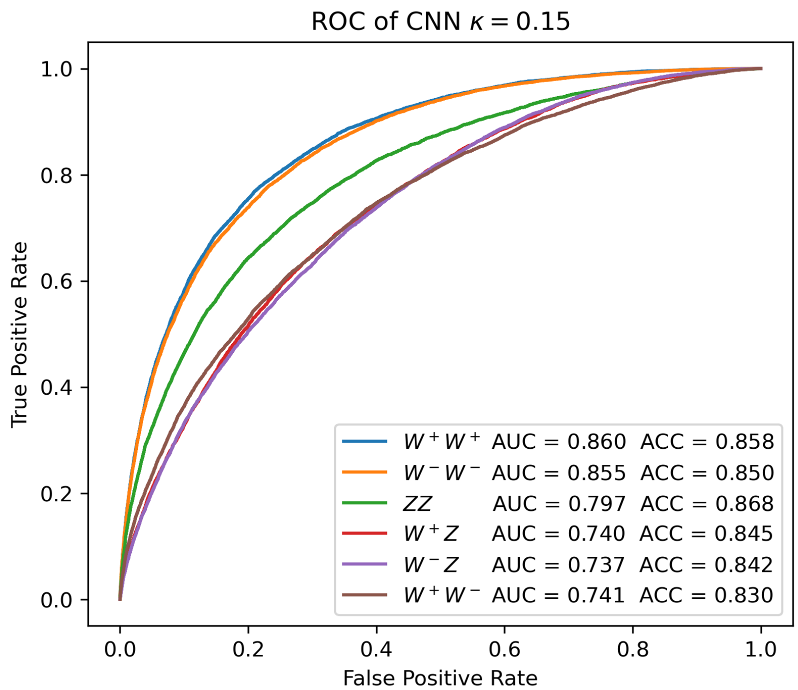


Figure 21: CNN's ROC of each event type. $\kappa = 0.15$.

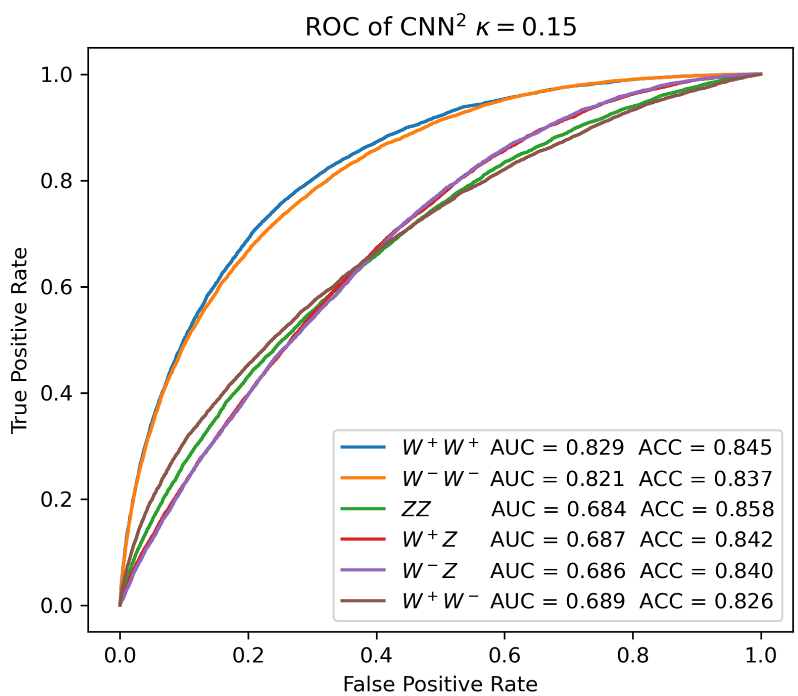


Figure 22: CNN^2's ROC of each event type. $\kappa = 0.15$.

10 Requirements of forward jet

In this section, the event selection criteria are modified. The $\Delta\eta$ and p_{T} cuts on the forward jets were applied. The event image constructed method remained the same as the Sec. 7.2.

10.1 Full event sample selection

The requirements of vector boson jet:

1. The transverse momentum of vector boson jets are required $p_{\mathrm{T}} \in (350, 450)$ GeV and in range $|\eta| < 1$.
2. Merging: The angular distance between the two quarks decayed from the vector boson is required $\Delta R(q_1, q_2) < 0.6$.
3. Matching: The vector boson and jet are matched if $\Delta R(V, j) < 0.1$.

The events with less than two matching vector boson jets will be discarded.

The forward jets are selected by the two highest p_{T} jets from the remaining jets and need to satisfy the following requirements:

1. The transverse momentum of forward jets are required $p_{\mathrm{T}} > 30$ GeV.
2. The difference of pseudorapidity of the two forward jets is required $|\Delta\eta| > 2$.

The event will be discarded if the forward jets can not pass the above requirements.

10.2 Training results

Select the samples again, where the forward jet cuts were applied. The event sample size for each type is presented in Table 17

Table 17: The sample size for each type. 80% samples are used in training, and 20% samples are used in testing.

Case	κ	W^+W^+	W^-W^-	ZZ	W^+Z	W^-Z	W^+W^-
1	0.15	36k	37k	29k	32k	33k	36k

The training results are summarized in Table 18. The training results are a little worse than Table 16.

Table 18: The training results of the full event. The forward jet cuts were applied to the samples.

	Sample	Overall ACC	W^+W^+ AUC	W^+W^+ ACC	W^-W^- AUC	W^-W^- ACC	ZZ AUC	ZZ ACC	W^+Z AUC	W^+Z ACC	W^-Z AUC	W^-Z ACC	W^+W^- AUC	W^+W^- ACC
CNN	1	0.440	0.858	0.858	0.849	0.849	0.791	0.868	0.731	0.845	0.729	0.837	0.736	0.827
CNN^2		0.374	0.831	0.846	0.818	0.837	0.679	0.858	0.684	0.844	0.683	0.836	0.690	0.824

11 Change the resolution

This section changes the resolution of the event image. In the pixelating step, the 15×15 and 25×25 are used.

11.1 Training results of different resolution

The resolution in the pixelating step was changed to 15×15 and 25×25. Then use these samples to train the model. The training results are summarized in Table 19. When the resolution decrease, the overall accuracy also decreases.

The samples rescaled after pixelating are used in training to reduce the image size effect. For example, the image is pixelated with size 15×15, then rescale back to 75×75. The training results are shown in Table 20.

Table 19: The training results of the full event. The $N \times N$ means the resolution in the pixelating step.

	Sample	Overall ACC	W^+W^+ AUC	W^+W^+ ACC	W^-W^- AUC	W^-W^- ACC	ZZ AUC	ZZ ACC	W^+Z AUC	W^+Z ACC	W^-Z AUC	W^-Z ACC	W^+W^- AUC	W^+W^- ACC
CNN	75×75	0.440	0.858	0.858	0.849	0.849	0.791	0.868	0.731	0.845	0.729	0.837	0.736	0.827
CNN	25×25	0.378	0.830	0.845	0.820	0.838	0.692	0.856	0.685	0.841	0.687	0.836	0.690	0.827
CNN	15×15	0.349	0.814	0.843	0.806	0.832	0.614	0.857	0.668	0.839	0.668	0.835	0.669	0.827

Table 20: The training results of the full event. The samples are rescaled back to 75×75.

	Sample	Overall ACC	W^+W^+ AUC	W^+W^+ ACC	W^-W^- AUC	W^-W^- ACC	ZZ AUC	ZZ ACC	W^+Z AUC	W^+Z ACC	W^-Z AUC	W^-Z ACC	W^+W^- AUC	W^+W^- ACC
CNN	75×75	0.440	0.858	0.858	0.849	0.849	0.791	0.868	0.731	0.845	0.729	0.837	0.736	0.827
CNN	$25 \times 25 \rightarrow 75 \times 75$	0.390	0.837	0.845	0.826	0.839	0.706	0.858	0.694	0.846	0.694	0.837	0.697	0.826
CNN	$15 \times 15 \rightarrow 75 \times 75$	0.362	0.823	0.843	0.812	0.833	0.654	0.854	0.676	0.844	0.674	0.838	0.677	0.828

Compared to these two Tables, there is an improvement when the image size was rescaled back to 75×75.

12 Middle layer output

In this section, the middle layer outputs of the event image are printed out. The different resolution samples are used and the rescaled samples are also used. The same CNN structure is used for training.

The results are summarized in Figure 23.

(a) 75×75 (b) 25×25 (c) $25\times25 \to 75\times75$ (d) 15×15 (e) $15\times15 \to 75\times75$

Figure 23: The middle layer output of event image. The resolution 75×75, 25×25, and 15×15 are used. The rescaled ones are also shown for resolution 25×25 and 15×15.